*HIPPIE**

External collaborations	KTH, TUT, UU, LU, SOLEIL, CAT-C
Original budget and funders	69 MSEK, KAW and 12 Swedish universities
Official start	September 2011
Expected date of completion	Regular users spring 2017

HIPPIE is a state-of-the-art beamline for Ambient Pressure X-ray Photoelectron Spectroscopy (APXPS) and Ambient Pressure X-ray Absorption Spectroscopy (APXAS) designed to study reactive, catalytic, liquid, biological, and electrochemical samples in *in situ* or *operando* conditions, which are impossible to study with conventional electron spectroscopy. It offers world-leading opportunities for the study of samples in a wide range of different sample environments at excellent photon flux and resolution. The maximum attainable pressure in experiments will be unsurpassed by competing beamlines. Users within the catalysis, photocatalysis, surface science, applied surface science, materials science, corrosion, thin layer growth, liquids & electrochemistry, biogeochemistry, and environmental chemistry research areas will be able to benefit greatly from this beamline.

Technical description

- High flux beamline (R>10000, 10^{13} photons/sec up to 1 000 eV) giving linear polarised light (109 – 2 000 eV) and inclined and circular polarised light (263 – 1 200 eV).
- Ambient pressure X-ray photoelectron spectroscopy (APXPS) at pressures up to at least 50 mbar.
- Dedicated sample environments designed to fulfil the needs of different user groups: Catalysis, High temperature treatments, Liquids and electrochemisty, Biology, and Photocatalysis.
- Excellent facilities for simultaneous APXPS, Polarisation modulated infrared absorption spectroscopy (PM-IRAS), and reactivity measurements (mass spectrometry). Off-line reactivity studies at up to 1 bar.
- Dynamic processes can be followed *in situ* down to the timescale of 10 ms using the fast 120 Hz detector of the APXPS electron analyser and the high flux from the beamline.

Present status

- All optics installed and beamline under ultrahigh vacuum (UHV).
- Beamline commission with X-ray starting in October 2016.
- Factory acceptance test of endstation completed in September, delivery in October.

Expected status end 2018

- Normal user operation with full functionality as described above.
- The beamline serves the already established MAX-lab APXPS user community within the areas of surface science, corrosion, catalysis, thin layer growth, water and environmental chemistry.
- New user groups from the areas of electrochemistry, bio(geo)chemistry, energy have been attracted to the beamline. Industrial contacts initiated.

Major partners and additional funding

- MAX IV-SOLEIL funding, CAT-C collaboration with Aarhus University and Haldor Topsøe A/S.
- KTH Royal Institute of Technology, Tampere University of Technology, Uppsala University, and Lund University

Changes made since the start

PM-IRAS instead of scanning electron microscopy (SEM) since a high quality UHV compatible SEM was too expensive for our budget.

Comparison to beamlines world wide

The HIPPIE beamline surpasses or matches the energy range, pressure range, sample environment, and scientific profiles of the following beamlines:

ALS (USA): BL 11.0.2 (90-1 500 eV, ca. 25 mbar max. pressure), BESSY II (Germany): BL ISISS (80-2 000 eV, ca. 20 mbar maximum pressure), Diamond Light Source (UK): BL VERSOX (250-2 800 eV, ca. 5 mbar

* https://www.maxiv.lu.se/accelerators-beamlines/beamlines/hippie/

maximum pressure), NSLS-II (USA): BL CSX-2 (250-2 000 eV, ca. 25 mbar maximum pressure), SSRL (USA): BL 13.2 (200-1 100 eV, ca. 100 mbar maximum pressure),

Future development

Many of the developments below will be coordinated with other beamlines, in particular SPECIES.

A. For the benefit of our users a common surface science and material laboratory (comparable e.g. to facilities at SOLEIL, DESY) for *ex situ* preparation and characterisation would be most useful.
B. Time resolution is a central issue and two important developments would be:
    (a) Equipment for following chemical kinetics on the ms-hrs scale. Requirements: Routines for "big data" treatment, TAP (Temporal analysis of products) equipment
    (b) Development of pump-probe measurements for studying phenomena on ps-µs time scale. Requirements: Delay-line-detector (DLD), laser setup and safety infrastructure, development of routines for "big data" treatment
C. Spatial resolution is another central issue. Today 5 µm line spatial resolution is possible with the capabilities of the electron energy analyser. This could be further extended by either means for high precision sample rotation or by focusing and baffling the beam.
D. The beamline provides excellent opportunities for dichroic measurements. Needed for magnetic measurements: magnetic coils & appropriate chamber.
E. New user communities can relatively easy be achieved by the construction of new ambient pressure (AP) cells. In particular we think of the following:
    (a) Industrial and/or inexperienced academic users with the need of fast access for *ex situ* prepared samples and data analysis services require fast sample load lock, automation of sample transfer and sample approach to nozzle, automated gas dosing, automated measurements, an in-vacuum sample garage, and analysis routines.
    (b) Atmospheric sciences. AP cell.
    (c) ALD and CVD. AP cell with dedicated gas system.
    (d) Cluster sciences, free and deposited. AP cell/chamber, cluster production source.
F. Implementation of angle-resolved measurements for band structure measurement and photoelectron diffraction. The prerequisites exist, but as with spatial resolution sample rotation is a prerequisite. Requirements: see point B above.

Further, we see a clear case for a second branch line on HIPPIE. Building on and extending the original proposal for the HIPPIE, where a UHV XPS endstation was foreseen, which was deemed indispensable by the reviewers of this original proposal, we would like to address the UHV XPS/XAS communities, the growing magnetism community, and the industrial community. We propose a UHV XPS/XAS endstation combined with spin-resolved XPS as well as facilities for XMCD (coils required). Further, the endstation would feature the possibility of multi-sample monitoring and fast multi-sample entry. Resources: endstation with spin-resolved electron energy analyser, XAS detector, manipulator with LN2/He cooling, multi-sample loadlock & garage, refocusing mirror chamber and mirror.